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(56) Documents cited
GB 1513362 US 4499405
GB 1199282 US 4333036
GB 1109023 US 4061944
DE A1 3403726 US 3863163

(58) Field of search
H1D
Selected US specifications from IPC sub-class H01J

(54) Electron beam irradiation apparatus

(57) The apparatus, which is for desulphurating and/or denitrating flue gases, has at least two large area cathode systems (3a, 3b) arranged in a vacuum casing (6), the casing being provided with electron emission windows of the same length and breadth as the respective cathode systems (3a, 3b).

As described, each window has a frame 1 and a titanium sheet (9) supported by bridge elements (8, Figs. 4 and 5). The frame (1) may be water cooled. The bridge elements may also have water cooling channels or may be of solid construction.

Fig.3

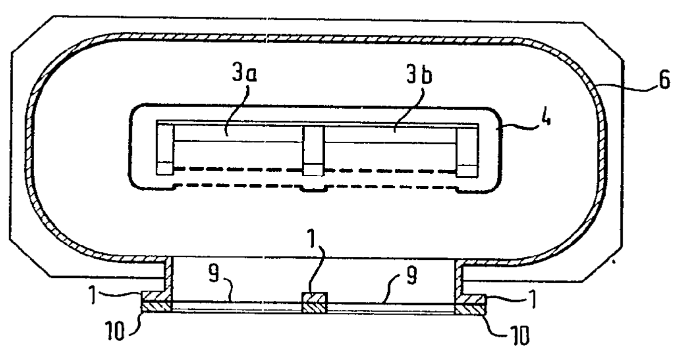

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Fig.1

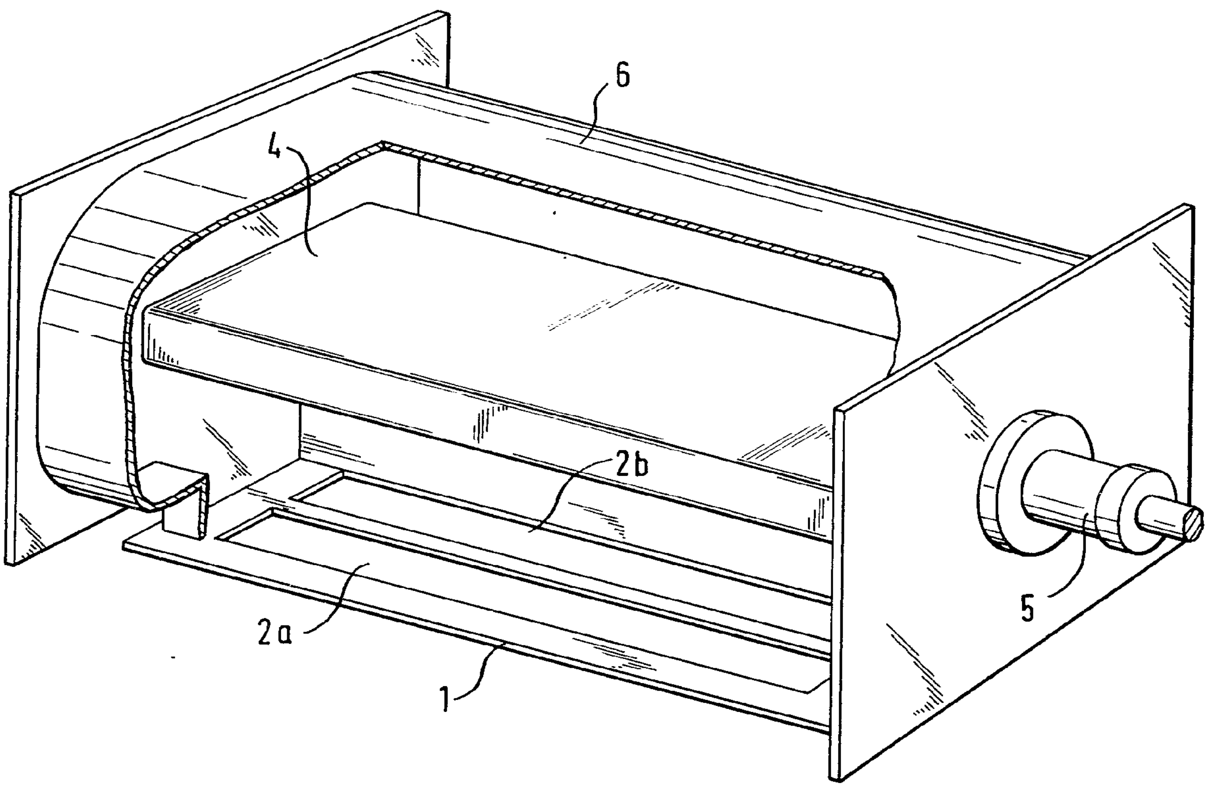

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Fig.2

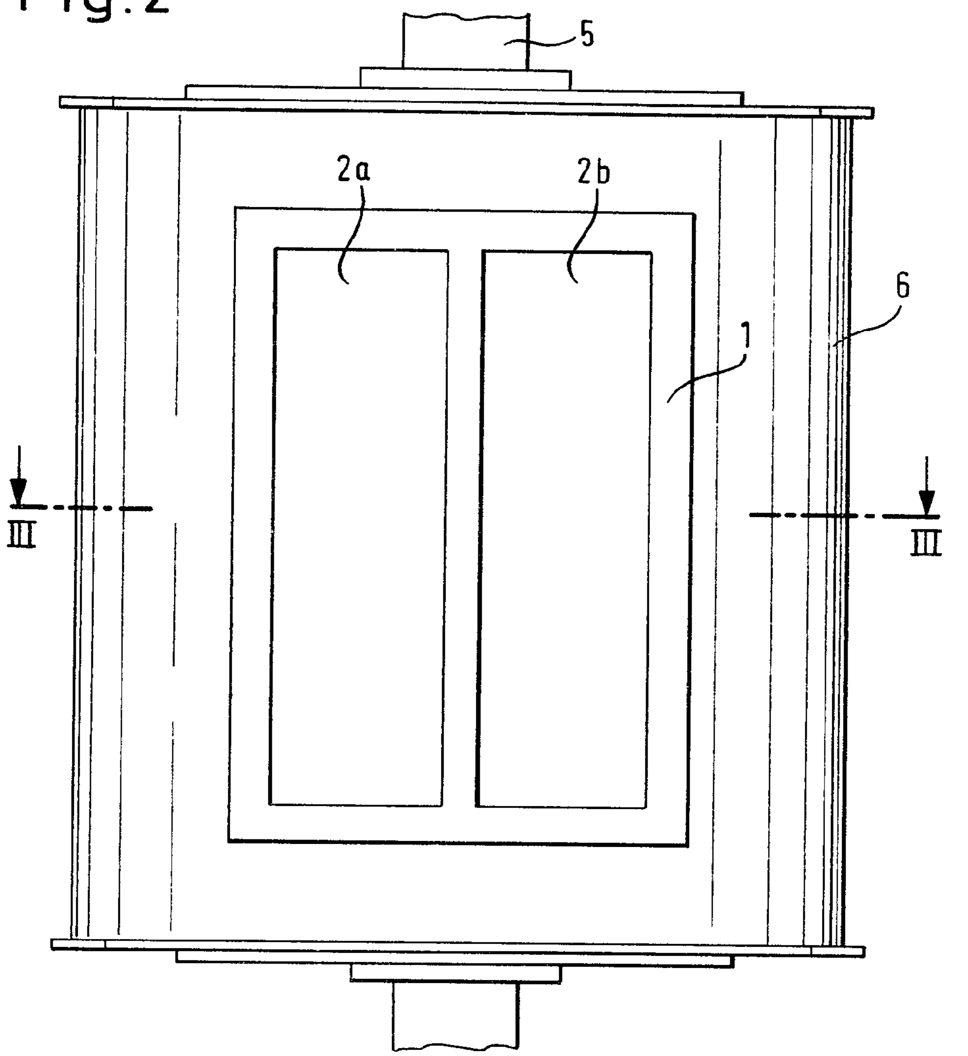


Fig.3

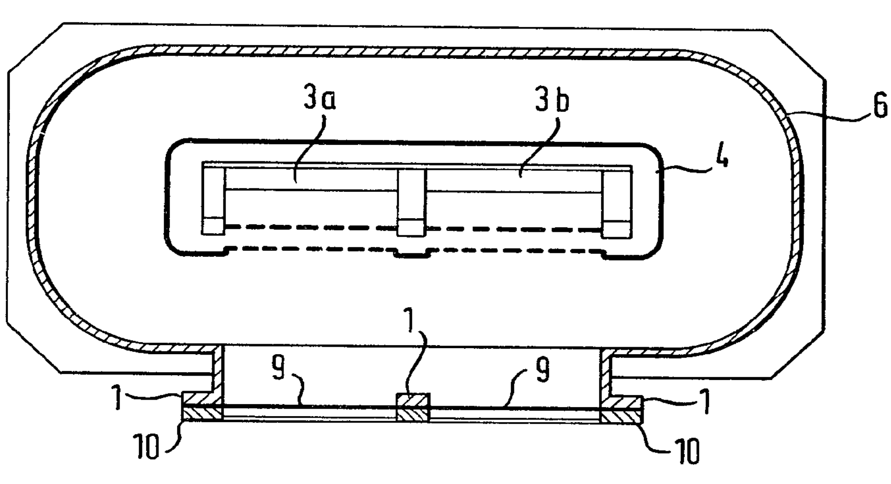


Fig. 4

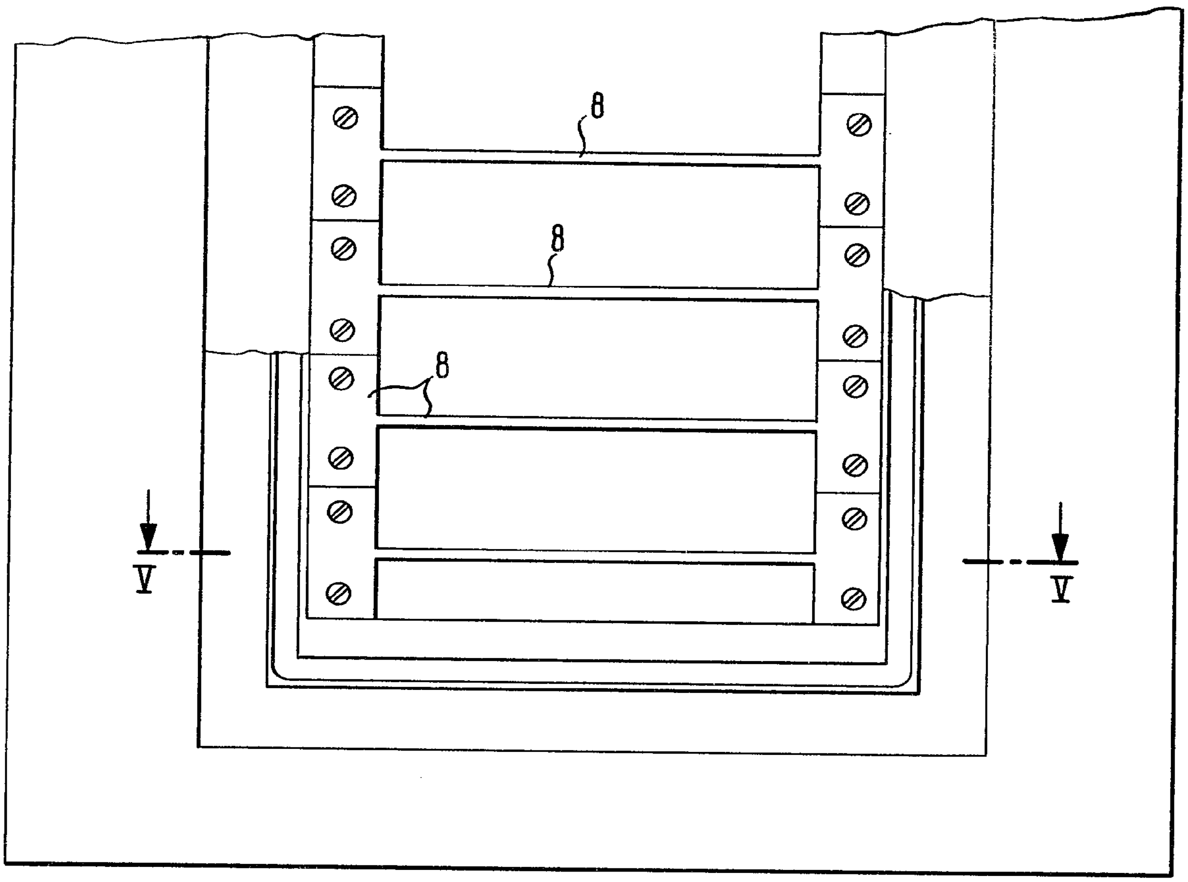


Fig. 5

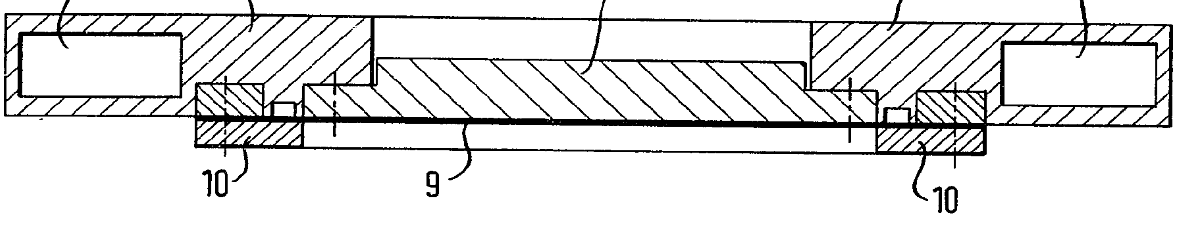


Fig. 7

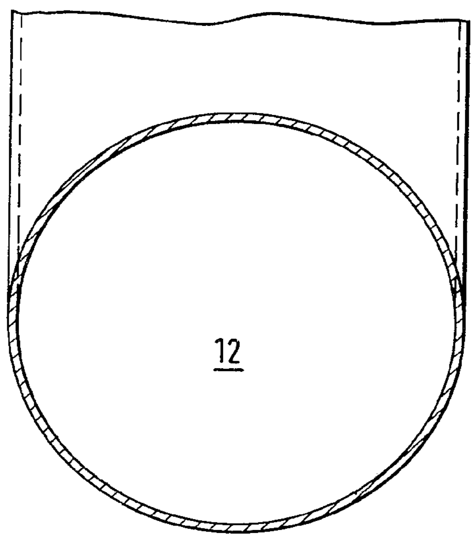


Fig. 8

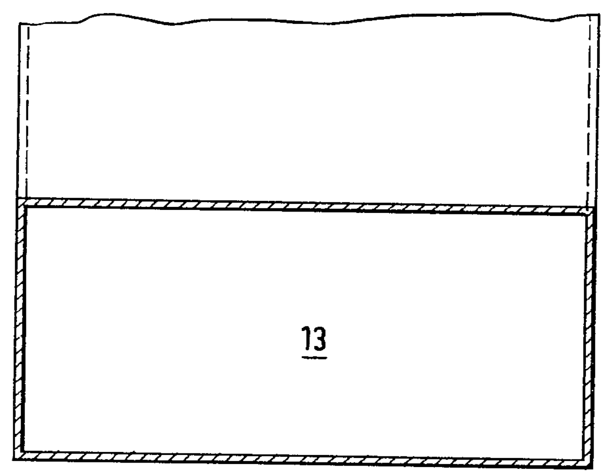
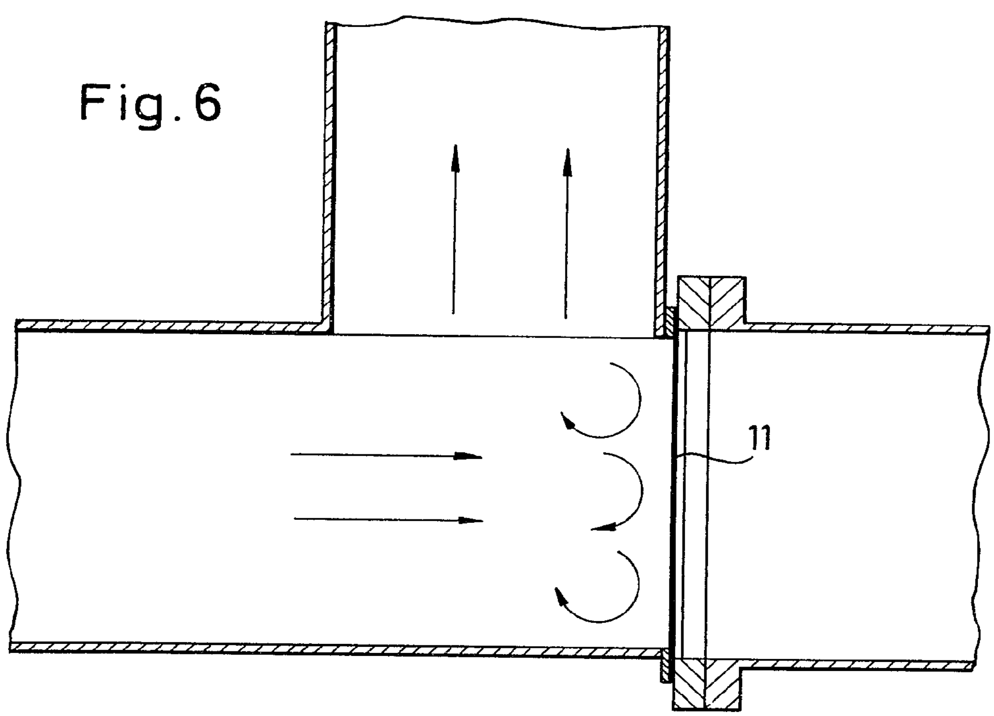


Fig. 6



SPECIFICATION

High performance low energy electron gun for desulphurating and/or denitrating flue gases

The present invention relates to high performance low energy electron guns for desulphurating and/or denitrating flue gases.

DE-A-34 03 726 describes in detail the desulphuration and denitration of flue gases through irradiation with so-called low energy electrons. The disadvantage of of this process and the device used is that only relatively small quantities of flue gas can be treated, as the electron guns are only equiped with one point cathode and an electron beam deflector (scanning principle), and due to the limited electron emission from the point cathode the high performances required cannot be achieved.

Although US-A-3 863 163 discloses an electron gun with a large area cathode system used for irradiating web shaped material, the capacity of such an electron gun is still not sufficient to desulphurate and/or denitrate flue gases on a larger technical scale.

The object of the invention is therefore to create a simple one-step electron gun with as high a beam potential as possible and with an electron stream about 10 times greater than the electron gun described in DE-A-34 03 726, which can desulphurate and/or denitrate flue gases on a large scale where stream speeds in the exhaust gas channel of 15 to 25 m/s are usual making certain cross sections for the flue gas channels necessary with regard to the electron penetration depth and distribution. In addition, for the irradiation of flue gases the cathodes and electron emission windows must have long service lives with loads per area unit of 0.15 mA/cm^2 in the beam producing device and electron emission window not being exceeded.

The present invention solves this problem by using low energy electron guns which attain the required performance through the fact that two large area cathode systems are arranged in parallel in a vacuum housing, each large area cathode system having its own electron emission window of the same length and breadth as the large area cathode system.

The upper limit of one step electron acceleration is at present around 300 kV. It is conditioned by the maximum attainable breakdown field strength for high voltages in a vacuum, which are essentially dependent on the material and surface condition of the electrodes.

In the irradiation of flue gas the efficiency of the electron accelerator used for irradiation plays a considerable part. The total irradiation capacity used is extremely high. Therefore the losses incurred through producing the electrons and when the electrons pass through the electron emission window should be kept to a minimum. In order to minimise the losses incurred when the electrons pass through the electron emission window two solutions are availabe:

1. A supported large area window which is water-cooled on the vacuum side as described in German Patent 26 06 169.

2. A quasi self-supporting window with only occasional copper support bridges without water-cooling, transverse to the longitudinal plane of the window. These support bridges bear a titanium sheet and are only a minor "shadow" to the electron beam. The design of these support bridges is identical to the double comb type support mesh in German Patent Specification 26 06 169 but the comb teeth are missing. The support bridges are not soldered into the window frame but are screwed into it. Water cooling of the support bridges is not necessary. The window frame is water-cooled. Heat absorbed by the support bridges is removed via the window flange. The window sheet itself is cooled by the flue gas to be irradiated, which flows past the window sheet in a turbulant stream.

There is a further embodiment of the window cooling in which cold air or cooled flue gas is blown via a blower or a side channel compressor onto the window sheet, independently of the flue gas.

The basis for calculating the electron penetration depth and the dose with which the material is to irradiated is given in detail in the applicant's DE-A-34 03 726.

High performance electron guns according to the invention which have a low dosage rate due to the large electron emission windows are ideally suited to the flow conditions of flue gas in power stations. In addition it is possible to irradiate a large quantity of flue gas with a minimum number of electron guns.

Low dosage rates mean a relatively low current load on the cathode and the electron emission window per unit area, resulting in an extremely long service life for the working parts, which is particularly noticeable in electron guns according to the invention.

If, as a result of new knowledge, chemical reactions with a radiation dose requirement of more than 0.5 to 1 Mrd are necessary for the simultaneous removeal of SO_2 and NO_x, the large area cathode system can be extended from two cathodes to three or more arranged in parallel. The radiation capacity increases accordingly.

DE-A-34 04 726 describes a flue gas pipe parallel or vertical to the longitudinal plane of the electron emission window. "Regularisation" of the dose is achieved by two-sided irradiation in an almost regular dose field. On the other hand a turbulent gas flow is required which through its movement imparts to each gas particle a medium-sized dose according to the radiation strength.

In another embodiment of the flue gas pipe the gas stream hits the electron emission window face vertically and is turbulently directed away vertically to the direction of impact. The electron emission window face can be rectangular or round. The type with the round design is of interest for flue gas irradiation systems with a smaller throughput. A scanning system as in DE-A-34 03 726 with a circular electron beam

deflector is placed directly on a round flue gas pipe. The irradiated flue gas is removed vertically to direction of its admission.

Embodiments of the invention will now be described, by way of example only, with reference to Figures 1 to 8 of the drawings and Examples 1 and 2 below.

In Figures 1 to 8 of the drawings, the reference numerals denote the following items:

1. Window frame
2a,2b Electron emission window
3a,3b Large area cathode systems, each attached to electron emission windows 2a, 2b.
4. Container for large area cathode systems.
5. High voltage lead and lead from the large area cathode systems.
6. Vacuum housing
7. Channels for water cooling of the window frame.
8. Screwed-in bridging elements.
9. Titanium sheet.
10. Sheet stretching frame.
11. Electron emission window face.
12. Round electron emission window face.
13. Angular electron emission window face.

Figure 1 shows in a schematic perspective, a view into an electron gun according to the invention, although the two large area cathode systems 3a, 3b located above the electron emission windows 2a, 2b are not visible.

Figure 2 shows a view from above of the electron emission window face 2a, 2b.

Figure 3 shows a cross section through the electron gun along line A-A in Figure 2. This figure clearly shows the two large area cathode systems 3a, 3b in the common container 4, which is located in the vacuum housing 6.

Figure 4 shows a view from above of a part of the electron emission window. This is similar to that of German Patent Specification 26 06 169, but with the modification that the double comb type bridging elements have no comb teeth and no boring used as a cooling pipe, but are solid and made, for example, from copper.

Figure 5 shows a section along the line B-B in Figures 4. The bridging elements 8 are screwed into the window frame 1 which has channels 7 for water cooling. The titanium foil 9 is supported on bridging elements 8 and is held at the window frame 1 by means of foil stretching frame 10 to hermetically seal the vacuum casing 6.

Figure 6 shows a section through the electron emission window face 11. The flue gases strike the window face 11 vertically and are removed at right angles to the window face 11, forming turbulence which increases the efficiency of irradiation.

Figure 7 shows a round version 12 of the electron emission window face.

Figure 8 shows an angular version 13 of the electron emission window face.

The following two examples show the use of electron guns according to the invention in large technical systems.

Example 1

Electron gun for large-scale desulphuration and/or denittration of flue gases

Conditions
250 kV Acceleration voltage
1.5 mA Window load with 10cm wide electron emission window.
Gas flow: 15 m/s or 20 m/s
Two sided irradiation
Distance between the electron guns 750 mm
Length of window 2,000 mm

Calculation
Cross section of flue gas channel 1.5 m^2
Quantity of flue gas
– at 15 m/s 22.5 m^3/s = 81,000 m^3/h
– at 20 m/s 30.0 m^3/s = 108.000 m^3/h

There are 22.5 kg/s or 30.0 kg/s of material to be irradiated.

Conversion formula

$$1\ \text{Mrd} = \frac{10\ \text{kJ}}{\text{kg}} = \frac{10\ \text{kW.s}}{\text{kg}}$$

or

$$1\ \text{kg} = \frac{10\ \text{kW.s}}{1\ \text{Mrd}}$$

These represent

$$22.5\ \text{kg} = \frac{225\ \text{kW.s}}{1\ \text{Mrd}}$$

or

$$30.0\ \text{kg} = \frac{300\ \text{kW.s}}{1\ \text{Mrd}}$$

Realization of 225 kW or 300 kW electron beam capacity

Efficiency 50% in electron gun

Loss of electron velocity in the window from 250 kV to 140 kV is compensated for by the penetrability which is over 50% at this high beam potential, with the result that an efficiency of 50 % can be attained.

Therefore the guns must have a total capacity of 450 kW or 600 kW.

Electron gun design

Electron emission window 2 × 25 cm × 2m per gun.

This window can take loads of 2 × 3.75 mA/cm electron radition.

This results in a total emission capacity of 2 × 3.75 mA/cm × 200 cm = 1.5 A or 375 kW/gun.

With two electron guns located directly opposite each other this results in a capacity of 750 kW or 375 kW effective radiation capacity in the reaction channel.

Requirements:

– at 15 m/s 225 kW effective electron emission capacity
– at 20 m/s 300 kW effective electron emission capacity.

This means that the electron guns are working at 60% capacity in the first case and 80 % in the second case.

Conversion to large power station

Since the gun of this example can handle flue gases in a quantity 81,000 m^3/h and a typical flue gas temperature is 90°C, this is equivalent to 63,000 Nm^3/h (where Nm^3/h is m^3/h under normal conditions i.e. 0°C and 760 mm Hg pressure). Now, since Nm^3/h . 1/3000 = electrical output in MW, approx. 21MW electrical output can be handled per flue gas channel.

Thus approx. 5 flue gas channels are needed in a 100 MW electric power station.

This calculation applies to a radiation dosage of 1 Mrd.

Example 2

Another large scale technical solution for irradiating flue gas can be as follows:

– beam potential of the electrons 300 kV
– mean velocity of the electrons after passing through the electron emission window 280 kV
– total current of electron accelerator 1500 mA
– max. electron current in the object with water-cooled window 750 mA.
– max. electron current in the object with gas-cooled window 1162.5 mA
– corresponding to an effective radiation output of 210 kW in the first case or 325.5 kW in the second case
– depth of the flue gas channel in two sided irradiation 1000mm
– surface area of the electron emission window 2000 × 500 mm
– cross section of the flue gas channel 2 m^2
– flue gas throughput at 15 m/s or 15 m/s velocity:
30 m^3/s = 108,000 m^3/h or
50 m^3/s = 180,000 m^3/h

These are 30 kg/s or 50 kg/s of irradiation material.

The following applies for the absorbed radiation dose

$$1\ \text{Mrd} = 10\ \text{kGy} = \frac{10\ \text{kg}}{\text{kJ}} = \frac{10\ \text{kW.s}}{\text{kg}}$$

With a dose of 1Mrd for flue gas treatment, 21 kg/s of flue gas can be irradiated by the above electron guns in the first case and 32.5 kg/s in the second case.

With a dose of 0.5 Mrd the corresponding values are 42 kg/s in the first case or 65 kg/s in the second case.

The flue gas flows transversely to the length of the electron emission window.

Conversion for a large power station:

108,000 m^3/h or 180,000 m^3/h of flue gas correspond to 83,000 Nm^3/h or 139,000 Nm^3/h of flue gas and as a rough estimate Nm^3/h flue-gas . 1/3000 = electrical output of a power station in MW

Thus at 15 m/s approx. 27 MW and at 25 m/s approx. 46 MW electrical output can be handled per flue gas channel.

Thus in a 100 MW power station 3-4 flue gas channels would be needed at 15 m/s and 2-3 flue gas channels at 25 m/s, according to the required radiation dose.

CLAIMS

1. A high performance low energy electron gun for desulphurating and/or denitrating flue gases, comprising a vacuum casing, at least two large area cathode systems arranged in parallel in the vacuum casing, each large area cathode system having its own electron emission window which is of the same breadth and length as the large area cathode system.

2. An electron gun according to claim 1, in which the electron emission windows have a support mesh composed of several double comb type bridging elements detachably connected to a window frame, and connected together by a boring acting as a cooling pipe.

3. An electron gun according to claims 1 and 2, in which the electron emission windows are quasi self-supported and in which the double comb type bridging elements are replaced by solid copper bridging elements without comb teeth which are screwed into the window frame, the latter being water cooled.

4. A high performance low energy electron gun for desulphurating and/or denitrating flue gases, substantially as herein described with reference to the drawings and/or the Examples.

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